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FOURTH QUARTERLY REPORT

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER

Covering

DEVELOPMENT OF SEALED LOW RATE SILVER OXIDE-ZINC CELLS

Period August 22, 1962 - December 21, 1962

Contract NAS5-1607

ESB Report No. E-96-62

THE ELECTRIC STORAGE BATTERY COMPANY
MISSILE BATTERY DIVISION
RALEIGH, NORTH CAROLINA

December 21, 1962

OTS PRICE
XEROX $ 2.60 ph
MICROFILM $ 1.07 mf.

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I. STATUS SUMMARY

A. Introduction. - This is the Fourth Quarterly Report, covering the period August 22, 1962, to December 21, 1962, on Contract NAS5-1607, which was awarded to The Electric Storage Battery Company by the National Aeronautics and Space Administration, Goddard Space Flight Center, on November 21, 1961. The following reports have been submitted on this contract previously:

1. First Quarterly Report (ESB Report No. E-21-62) submitted March 27, 1962.
2. Second Quarterly Report (ESB Report No. E-33-62) submitted May 22, 1962.
3. Third Quarterly Report (ESB Report No. E-65-62) submitted August 17, 1962.

B. Program Objectives. - The general objective of the development program is to design, develop, and test a standard line of low rate, sealed, secondary silver oxide-zinc cells for space applications.

Specifically, three cell sizes (rated at 20, 50, and 100 ampere-hours) of similar construction are to be developed with the following characteristics as design objectives:

1. Actual capacities of 30, 60, and 120 ampere-hours, respectively, when discharged at the 20-hour to 1-year rate to 1.1 volts per cell.
2. Open-circuit voltages of 1.86 volts per cell.
3. Operating voltages (at 20-hour to 1-year rate)

of 1.65 to 1.45 volts per cell.

4. Energy densities (at 20-hour to 1-year rate) of 65 to 75 watt-hours per pound and 5 to 6 watt-hours per cubic inch, based on first cycle output.
5. Operating life of 1 year.
6. Maximum shelf storage capacity loss of 1, 4, 10, and 20 per cent at 0, 22, 38, and 54 degrees C, respectively.
7. Position insensitivity.
8. Magnetic field intensity at a point three feet from the cell of 10^{-5} gauss or less.

C. Program Status. - All experimental work preceding the final design has been completed with the exception of testing cells, which are presently in charged storage for periods of six and nine months, and further cycling of cells containing a negative plate binder. A total of 84 of the 91 cells scheduled for test or shipment in the qualification lot have been completed and charged. The remaining seven cells (Model 217) are nearing completion. The proposed number of qualification cells, 20 Model 216, 10 Model 217, and 5 Model 218, were shipped to the Goddard Space Flight Center on schedule. Some of the tests to be performed by ESB on qualification lot cells have been completed, and the majority of the remaining tests are in progress.

II. WORK DURING REPORTING PERIOD

A. Cell Case Burst Pressure Tests. - Cycolac T-2502 was selected as the case material for the Model 216, 217, and 218 cells. Results of a comparative burst pressure test on Model 218 cell cases made from this material and from polystyrene RMD 4511 were given in the Third Quarterly Report (Page 5). The Cycolac case burst at 130 p.s.i.g. while the case molded with RMD 4511 burst at 45 p.s.i.g.

Model 216 and 217 cell cases were made with an adjustable mold constructed on this contract. The first preproduction samples submitted by the molder were rejected because the sidewalls were different thicknesses due to core "winking". This defect was corrected in a second preproduction submission by further bracing of the core. The mold was accepted on the basis of the second samples, and lots of 100 Model 216 and 200 Model 217 cases were produced. Two cases of each type were selected at random from both preproduction lots and the production cases for burst pressure tests with the following results:

		Cell Case Burst Pressure* (psig) Model 216	Model 217
First Preproduction Lot	Test #1	55	95
First Preproduction Lot	Test #2	60	77
Second Preproduction Lot	Test #1	50	87
Second Preproduction Lot	Test #2	90	100
Production Lot	Test #1	90	150
Production Lot	Test #2	90	115

*All tests conducted on unsupported cell cases at room temperature.

These burst pressures are far in excess of any pressure that should be generated within the cells for which these cases are used, provided the "Service and Operating Instructions" supplied with the cells are followed to the letter. As an additional precaution, the cells should be clamped across the short dimension while being charged, discharged, or during storage at temperatures in excess of 30° C.

B. Negative Plate Binder Studies. - Based on prior experimental work, polyvinyl alcohol (P.V.A.) is being evaluated as a negative plate binder. In an attempt to obtain some insight into the optimum concentration of binder to use, 1, 3, or 5 per cent finely ground P.V.A. was incorporated as a dry powder in negative active material mixes. Each mix was used to fabricate SS-7.5 negative plates for two cells.

The SS-7.5 sealed cell, a standard line high-rate unit with a nominal capacity of 7.5 ampere-hours, was selected for this experiment because it can be cycled in a relatively short period of time (charged at the 23-hour rate, discharged at the 1-hour rate, based on nominal capacity).

To date, five deep discharge cycles have been completed at the above rates. Discharge performance is illustrated in Figure 1, Page 20. No degradation of performance was observed over these five cycles; in fact, a trend toward a general capacity increase occurred. No correlation between per cent P.V.A. and performance was apparent.

Cell 4 polarized on the third discharge cycle but performed almost up to par subsequently. It has been observed in other binder test data that too high a concentration of gelling agent (or binder) sometimes leads to isolation of the active material from the plate grid structure. Optimization of design in watt-hours per unit volume also means elimination of excess inactive material.

It was concluded, therefore, that the addition of 1 per cent finely ground P.V.A. powder is an excellent substitute for the standard Teflon powder binder, as the data below shows.

Cycle No.	Discharge Capacity (A.H. at 1.0 Hour Rate) of Cells with 1% P.V.A. Min.	Max.	A.H./gm Ag (Max.)
1	10.5	10.6	0.316
2	11.6	11.8	0.352
3	11.1	11.1	0.332
4	11.3	11.3	0.338
5	11.8	12.2	0.364

C. Gas Recombination Studies. - Six 40 A.H. sealed cells were constructed with 0.064 inch "DP" positive plates, the standard separator system of one layer 0.005 inch Synpor and five layers 0.0009 inch cellophane, standard negative plates, and M40 electrolyte varying in volume per cell from no free electrolyte to a fully flooded condition. Two cells were potted improperly during the installation of pressure gages. The remaining four cells: S/N 31, 42, 48, and 52 have completed three full cycles to date. Table I, Page 14, summarizes pertinent data observed during the testing period. If the charge capacities and discharge capacities are summed over the first three cycles by electrolyte level as shown below, the conclusion may be drawn that either "dry" or "1/2 full" electrolyte levels are to be desired over the "flooded" condition. In the final cell designs the dry condition was selected to optimize weight as well as capacity delivered with minimum cell operating pressures.

	Electrolyte Level		
Parameter	Dry	1/2 Full	Flooded
Inputs, A.H.	172.0	175.3	165.4
Outputs, A.H.	151.4	153.9	143.5
Efficiency, %	88.0	88.0	87.0

D. Charged Retention of Sealed Low Rate Test Cells. - Low rate 30 A.H. sealed cells are on storage in the fully charged state at temperatures of 0, 50, 90, and 125°F. Table II, Page 15, summarizes the discharge capacities observed at the 100-hour rate after each storage period completed to date and gives the average capacity losses per month at each storage time, assuming no loss at the lowest storage temperature of 0°F. All storage tests will not be completed until March, 1963. At that time a set of capacity retention curves will be plotted to allow capacity losses to be estimated for any storage time and temperature within the experimental range of data. First estimates indicate capacity losses in per cent per month decrease with increasing storage time and with decreasing storage temperature.

E. Separator System for Final Cell Design. - Charged stand tests for two weeks at 160°F on unsealed S-7.5 cells containing 13 different separator systems demonstrated that the best two systems were:

1. 1 layer 0.001 inch EM 403 Dynel
   1 layer 0.005 inch Polypor WA
   4 layers 0.0009 inch 193 PUD-0 cellophane, and
2. 1 layer 0.005 inch ESB-Reeves white Synpor
   5 layers 0.0009 inch 193 PUD-0 cellophane

One lot of ESB-Reeves white Synpor was procured for the qualification cells when the decision was made to use the Synpor system. However, other lots of white Synpor available at ESB were at that time giving erratic performance on other contracts and analyses showed these lots had high starch content. This quality control problem suggested that the Synpor purchased for the qualification cells should be tested in batteries. A sample was, therefore, tested in conjunction with four layers of 193 PUD-0 cellophane in two sealed, high rate 25 A.H. cells. Figure 2, Page 21, shows the first, second, and third cycle discharge curves of the cells when discharged at 0.5 amp/in^2 (63.5 amperes).

The performance of the Synpor was good, and the lot was accepted for use in the Goddard cells.

At the same time a decision was made to use separator system (E-1) in the Model 218 cells to provide a comparison of the two separator systems in the qualification test cells. No quality control problems have been observed on either the Polypor WA or the EM 403 dynel. No problems of separator system in the qualification test cells are thus expected. It is, however, believed that all the storage experiment cells have the questionable lot of white Sympor. This fact might explain the erratic behavior observed in these cells to date.

F. Production of Qualification Test Cells. - Production drawings for each of the following cell sizes were completed and submitted to the Engineering Pilot Line for production of the following qualification test cells:

Model No.	Rated Capacity (A.H.)	Actual Capacity (A.H.)
216	20	30
217	50	60
218	100	140

Production proceeded with no difficulties except in the following areas:

1. Adjustment of electrolyte level prior to the first sealing operation; and
2. Elimination of bubbles in final epoxy seal beneath cell cover plate.

A total of 35 cells were shipped to Goddard on schedule. Table III, Page 15, gives the charge inputs and weights for each of the 20 Model 216, 10 Model 217, and 5 Model 218 cells shipped and the manner of their selection from the qualification lots. Table IV, Pages 17-18, shows the input capacities of the remaining cells made to date and the test scheduled for each. Table V, Page 19, summarizes the operational data obtained to date on the qualification test cells discharged at the 20 and 100 hour rates. Relatively poor performance was observed from those cells with improper electrolyte adjustment: Model 216, S/N 13 and 32 and, Model 218, S/N 3 and 17. This problem was solved subsequently.

The bubble problem in the final seal was solved on some of the qualification cells by drilling through the cell cover into the bubble void, filling with epoxy mix, and then resealing with polystyrene cement. In later cells the bubbles were removed by a superior potting technique before the epoxy cured out.

Figures 3, 4, and 5, Pages 22, 23, and 24, show plots of 20 and 100 hour rate discharges of the Model 216 217, and 218 cells at 50, 78, and 125°F. Figure 6, Page 25, shows 5 second loaded voltages for each of the cell types as a function of discharge current density. The upper curve of each pair of curves shows the voltages observed on fully charged cells as currents were increased from zero current. The lower curve of each pair shows voltages observed when the current was decreased stepwise in the same load intervals to zero current. Estimated operating voltages at 78°F should fall between or near these curves for fully charged cells. Charged stand will drop the voltages slightly, especially after storages at temperatures in the range of 90 to 125°F.

G. <u>Operating Instructions</u>. - Service and Operating Instructions, Document No. 47a, was prepared for use by Goddard in testing the qualification cells and was included with the cells shipped to Goddard Space Flight Center on November 23, 1962. Revision "a" of December 5, 1962, corrected the full charge current listed on Page 4 for Model 217 batteries to the proper value of 1.15 amperes.

Intercell connectors are being designed for the Model 216, 217, and 218 cells. One connector for each cell shipped will be forwarded to Goddard. Operating as many as six cells of any of these models in series would require no departures from Service and Operating Instructions, No. 47a, except multiplying cutoff voltages by the number of cells involved.

III. FUTURE WORK

A. Fabrication and Test of Remainder of Final Cells. - Seven Model 217 cells now on charge will be completed and placed on test according to the schedule of Table IV, Pages 17-18, which will be implemented in full.

B. Storage Tests. - Charged stand tests at 0°F and 50°F will be completed and data submitted to Goddard Space Flight Center by March 21, 1963.

C. Final Report. - A comprehensive final report summarizing the entire contract work will be prepared for submission to Goddard Space Flight Center not later than January 21, 1963.

IV. EXPENDITURES AND MAN-HOURS

A chart showing expenditures to November 30, 1962, compared to a linear rate of expenditures over the contract period is given in Figure 7 Page 26. Engineering man-hours worked to December 9, 1962, are plotted in Figure 8, Page 27. A schedule of engineering and production hours is tabulated below:

		Engineering and Production Hours				
Employee	Function	11/21/61 to 2/25/62	2/26/62 to 5/13/62	5/14/62 to 8/12/62	8/13/62 to 12/9/62	Total
A.M. Chreitzberg	Mgr. Adv. Development	75.0	59.0	14.0	19.0	167.0
D.B. Colbeck	Proj. Engineer	138.0	273.0	134.0	103.0	648.0
J.F. Szabo	Proj. Engineer	15.5	261.5	5.5	0.0	282.5
A.H. Haddock	Test Engineer	0.0	43.0	24.0	47.0	114.0
L.V Rajagh	Chem. Tech.	7.0	206.0	165.5	22.0	400.5
H.G. Heinsohn	Elec. Tech.	0.0	158.0	114.0	26.0	298.0
W.R. Wright	Test Tech.	0.0	50.0	45.5	82.0	177.5
W.T. Whitley	Elec. Tech.	0.0	0.0	177.0	3.0	180.0
A.G Alexander	Elec. Tech.	0.0	0.0	8.0	43.5	51.5
	Pilot Plant Supervision	6.0	17.5	0.0	60.5	84.0
	Tool Design	0.0	47.0	43.0	4.0	94.0
	Drafting	0.0	5.0	0.0	80.0	85.0
	Pilot Plant & Test Hourly	26.5	247.7	288.5	681.3	1,244.0
	Prod. Supvn.	0.0	0.0	0.0	61.0	61.0
	Prod. Hourly	0.0	26.8	3.0	130.5	160.3
	Mach. Shop (Hrly)	0.0	81.5	40.5	98.0	220.0
	Total Hours:	268.0	1,476.0	1,062.5	1,450.8	4,267.3

V. SUMMARY AND CONCLUSIONS

A. Summary of Work Accomplished During Reporting Period. -

1. Burst pressures of Cycolac cell cases were measured at 78°F with cases unsupported. The minimum burst pressure of cases from production lots was 90 psig Maximum cell operating pressures rarely exceed 20 psig.

2. Addition of finely ground, dry polyvinyl alcohol (P.V.A.) powder to negative plate mixes in 1, 3, and 5 per cent quantities maintained SS-7.5 cell capacity at high levels during cycling tests and appears to be a promising negative plate binder.

3. Sealed cells activated and then drained free of excess electrolyte were compared with sealed cells flooded with electrolyte, and with electrolyte half-way up the plates in cycling tests. Cells with essentially dry plates gave maximum over-all performance.

4. Thirty-five qualification cells were manufactured and shipped to Goddard Space Flight Center for testing.

B. Conclusions. - Qualification cells, based on knowledge gained during this contract, operate at the following energy densities:

Model No.	Discharge Rate (Hours)	Discharge Capacity A.H. To 1.3 V	Mean Voltage (Volts)	Energy Density* WH/Lb.	Energy Density* WH/In^3
216	20	37	1.51	68	5.4
	100	40	1.55	75	5.9
217	20	74	1.51	74	6.8
	100	80	1.55	82	7.5
218	20	160	1.50	80	7.6
	100	170	1.54	87	8.3

(*) At 78°F.

TABLE I

EFFECT OF ELECTROLYTE LEVEL ON PERFORMANCE
OF SEALED LOW RATE TEST CELLS

	Electrolyte Level In Cell			
	Dry	½ Full	Flooded	
Cell Serial Number	31	52	42	48
First Cycle: Input (A.H.) to 1.97 volts	61.4	63.5	59.1	61.1
Output A.H. (20 Hr. Rate (2.2 Amp) 50°F	43.6	40.1	42.9	45.8
Efficiency: A.H./gm Ag	0.249	0.229	0.244	0.262
% of Input	71	63	73	75
Second Cycle:* Input (A.H.) to 10 psig.	57.2	53.0	57.5	54.4
Charge cut-off voltage, volts	2.20	2.17	2.15	2.14
Efficiency: % of first cycle Input	93	84	97	89
% of first cycle Output	131	132	134	119
Pressure observed on stand after charge to 10 psig:				
After: 50 hrs.	5½	4½	7+	3½
140 hrs.	3½	3½	7	2
158 hrs.	3½	3	6½	0
Recharge capacity to 10 psig, A.H.	4.0	5.3	5.7	4.8
Total Input capacity, A.H.	61.2	58.3	63.2	59.2
Discharge at 50°F - 20 Hr. Rate:				
Lower, plateau voltage, volts	1.48	1.49	1.45	1.45
Output capacity, A.H.	61.4	61.0	59.9	32.1
Pressure at end of discharge, psig.	4	4	7+	3
Efficiency: % of 2nd cycle Input	100+	105	95	54
% of 1st cycle Output	141	152	140	70
A.H./gm Ag	0.350	0.348	0.342	0.183
Third Cycle: Input (A.H.) to 1.97 volts	49.4	53.6	43.1	32.4
Efficiency: % of 2nd cycle Output	80	88	68	101
Discharge at 78°F at 20 Hr. Rate:				
Lower plateau voltage, volts	1.51	1.51	1.51	1.51
Average voltage (Calc.), volts	1.519	1.531	1.512	1.509
Capacity, A.H.	46.4	52.8	40.7	67.1
Max. press during disch., psig.	3.5	3.0	6.0	3.5
Efficiency: Output as % of:				
3rd cycle Input	94	98	94½	207
2nd cycle Output	76	87	68	209
A.H./gm Ag	0.265	0.300	0.232	0.384
All Cycles: Net Input**, A.H.	20.6	21.5	21.9	7.7

(*) Pressure gages leaked on 1st cycle-repaired between 1st & 2nd cycle.
(**) Total Input minus total Output over 3 cycles.

TABLE II

CAPACITY RETENTION OF LOW RATE SEALED TEST CELLS DURING CHARGED STORAGE AT TEMPERATURES OF 0, 50, 90, and 125°F POSITIVE PLATE THICKNESS = 0.064 INCH

Storage Temperature °F		Residual Capacity - A.H. and Storage Time, Days: 23	38	58	97	S	$\bar{\bar{X}}$
125		25.9	29.4	20.5			
		23.3	24.0	--			
	S	49.2	53.4	20.5		123.1	
	$\bar{X}$	24.6	26.7	20.5			24.6
90		28.3	29.6	30.8	28.5		
		27.9	27.1	27.0	26.0		
	S	56.2	56.7	57.8	54.5	225.2	
	$\bar{X}$	28.1	28.3	28.9	27.3		28.1
50		30.8			30.6		
		26.0			26.6		
	S	56.8			57.2	114.0	
	$\bar{X}$	28.4			28.6		28.5
0		30.0			34.3		
		27.8			25.8		
	S	57.8			60.1	117.9	
	$\bar{X}$	28.9			30.1		29.5
Calculated capacity loss, in % of 0°F discharge capacity, per month of charged storage:							
125		21.6	7.5	15.8			
90		6.2	3.2	1.0	2.3		
50		4.9			0.94		

ESB/MRD
Raleigh, N. C.

TABLE III

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF QUALIFICATION CELLS SHIPPED TO GODDARD SPACE FLIGHT CENTER

	S/N	Input Capacity (Amp-hrs)	A.C.* Impedance (Ohms)	Weight (gm.)	S/N	Input Capacity (Amp-hrs)	A.C.* Impedance (Ohms)	Weight (gm.)
Model 216								
	3	44.0	0.44	377	19	44.5	0.46	381
	4	44.0	0.45	380	21	44.0	0.46	380
	5	43.8	0.45	379	22	44.0	0.45	375
	6	44.7	0.44	380	23	44.4	0.44	374
	7	44.0	0.44	380	26	44.3	0.46	376
	10	44.4	0.44	381	27	43.7	0.46	376
	14	44.0	0.45	377	28	43.2	0.46	374
	16	44.4	0.46	376	29	45.2	0.46	376
	17	44.0	0.44	377	30	43.3	0.46	375
	18	43.2	0.45	377	34	44.4	0.46	379
Model 217								
	3	85.8	0.29	667	17	83.7	0.26	667
	9	85.8	0.29	669	20	84.6	0.28	666
	10	84.6	0.28	662	23	84.4	0.28	662
	15	85.8	0.29	665	24	84.6	0.29	668
	16	83.2	0.28	664	27	83.2	0.28	660
Model 218								
	2	179.4	0.21	1330	10	182.1	0.23	1342
	6	179.4	0.24	1326	21	182.1	0.25	1316
	7	182.1	0.25	1342				

(*) This characteristic is determined prior to charge as a quality control measure to provide indication of satisfactory activation.

Selection of cells for shipment was based on input capacity as follows:

Model 216 - Median charge capacity of lot ± 30% of the range
Model 217 - Median charge capacity of lot ± 21% of the range
Model 218 - Median charge capacity of lot + 15%
- 0% of the range

ESB/MBD
Raleigh, N. C.

TABLE IV

TEST SCHEDULE FOR QUALIFICATION LOT CELLS TO BE EVALUATED AT ESB

	S/N	Input Capacity (Amp-hrs)	Nominal Discharge Rate (Hrs)	Disc. Curr. (Amp.)	Load Resistor (ohms)	Disc. Temp. (°F)	Special Treatment
Model 216							
	8	45.9	2000	--	105	Room	
	9	45.3	1000	--	52	Room	
	12	42.7	1000	--	52	125	
	15	42.2	2000	--	105	125	
	20	42.8	100	0.31	--	Room	Discharge after 2 month Storage at 125°F
	24	42.8	100	0.31	--	Room	Discharge after 2 month Storage at 125°F
	25	42.2	2000	--	105	50	
	31	42.8	1000	--	52	50	
Model 217							
	4	83.2	2000	--	52	50	
	5	81.2	1000	--	25	Room	
	6	85.5	2000	--	52	Room	Discharge upside down
	7	82.6	100	0.62	--	125	Discharge under vacuum
	8	87.8	2000	--	52	125	Discharge under vacuum
	11	86.0	2000	--	52	Room	
	12	86.5	1000	--	25	50	
	13	86.5	1000	--	25	125	Discharge under vacuum
	18	83.2	2000	--	52	50	Discharge upside down
	21	83.2	1000	--	25	125	
	22	85.8	2000	--	52	125	
	25	*	1000	--	25	50	
	26	82.7	20	3.10	--	125	Discharge under vacuum
	29	*	100	0.62	--	Room	
	30	*	20	3.10	--	Room	
	31	*	20	3.10	--	125	
	32	*	1000	--	25	Room	
	33	*	20	3.10	--	50	
	34	*	100	0.62	--	50	
Model 218							
	1	187.8	2000	--	23	125	
	4	177.9	100	1.39	--	Room	Discharge after 1 month storage at 125°F
	8	177.9	100	1.39	--	Room	Discharge after 2 month storage at 125°F
	11	176.1	100	1.39	--	Room	Discharge after 2 month storage at 125°F

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TABLE IV
(Continued)

TEST SCHEDULE FOR QUALIFICATION LOT CELLS
TO BE EVALUATED AT ESB

S/N	Input Capacity (Amp-hrs)	Nominal Discharge Rate(Hrs)	Disc. Curr. (Amp.)	Load Resistor (ohms)	Disc. Temp. (°F)	Special Treatment
Model 218						
12	177.1	100	1.39	--	Room	Discharge after ½ month storage at 125°F
13	174.8	1000	--	11.4	Room	
15	182.1	1000	--	11.4	50	
16	176.0	100	1.39	--	Room	Discharge after 1 month storage at 125°F
18	182.9	2000	--	23	Room	
20	189.7	2000	--	23	50	
25	181.4	1000	--	11.4	125	
28	177.1	100	1.39	--	Room	Discharge after ½ month storage at 125°F

Model 217 cells marked * in capacity column have not been completed. They will differ from the other 217 cells in that the separator system will be 1 layer of Polypor WA and 5 layers of cellophane instead of 1 layer of white Synpor and 5 layers of cellophane.

TABLE V

DISCHARGE PERFORMANCE OF QUALIFICATION LOT SEALED CELLS

	S/N	Input Capacity (Amp-Hrs)	Nominal Discharge Rate (Hrs)	Discharge Current (Amps)	Discharge Temp. (°F)	Output Capacity (Amp-Hrs)	% Of Input	Amp-Hrs Per Gram Of Silver	Watt-Hours	Cell Wt. (lb.)	Watt-Hrs Per Pound	Watt-Hrs Per Cu.In.
Model 216												
	1	41.2	20	1.55	50	36.7	89	0.319	55.5	.84	66.1	5.3
	32	40.4	20	1.55	Room	28.4	70	0.247	43.0	.79	54.4	4.1
	13	42.2	20	1.55	125	29.3	70	0.255	45.0	.83	54.3	4.3
	2	40.4	100	0.31	50	38.1	94	0.331	58.3	.83	70.2	5.6
	33	42.3	100	0.31	Room	39.9	94	0.347	61.9	.83	73.5	5.9
	11	42.8	100	0.31	125	36.2	85	0.315	56.5	.83	68.1	5.4
Model 217												
	1	79.3	20	3.10	50	73.6	93	0.322	110.4	1.50	73.6	6.7
	19	81.6	20	3.10	Room	77.5	95	0.338	117.9	1.47	80.0	7.2
	2	80.4	100	0.62	50	77.4	96	0.338	119.1	1.49	79.8	7.3
	28	76.7	100	0.62	Room	67.8	90	0.296	104.3	1.45	72.0	6.4
	14	86.6	100	0.62	125	78.4	90	0.342	122.3	1.51	81.0	7.5
Model 218												
	3	161.9	20	6.95	50	125.0	77	0.243	180.0	2.93	61.5	5.7
	17	152.4	20	6.95	Room	126.9	83	0.247	189.2	2.93	64.5	6.0
	22	177.5	20	6.95	125	163.5	92	0.318	250.4	2.96	84.5	7.9
	14	159.4	100	1.39	50	152.2	95	0.296	229.5	2.93	78.2	7.3
	19	194.8	100	1.39	Room	178.9	92	0.347	273.9	2.96	92.5	8.7
	23	182.9	100	1.39	125	170.5	93	0.331	266.2	2.94	90.6	8.5

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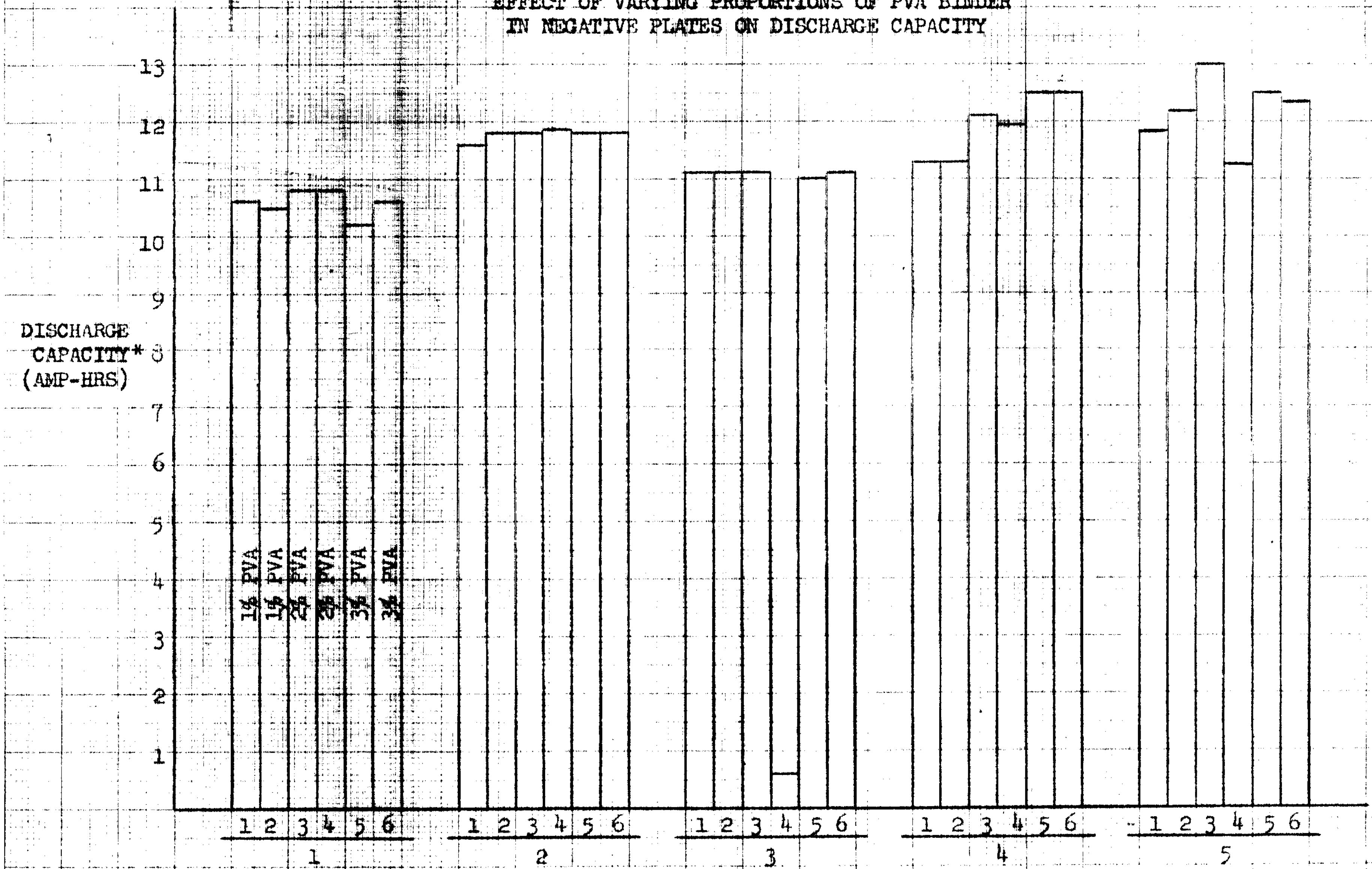
FIGURE 1

EFFECT OF VARYING PROPORTIONS OF PVA BINDER IN NEGATIVE PLATES ON DISCHARGE CAPACITY



(*) SS-7.5 cells discharged at 1-Hour rate at room temperature.

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FIGURE 2

DISCHARGE CURVES OF TWO SS-25 SEALED CELLS
USED TO EVALUATE SYNPOR FOR QUALIFICATION BATTERIES

DISCHARGE AT CONSTANT CURRENT OF 63.5 AMPERES AT ROOM TEMPERATURE

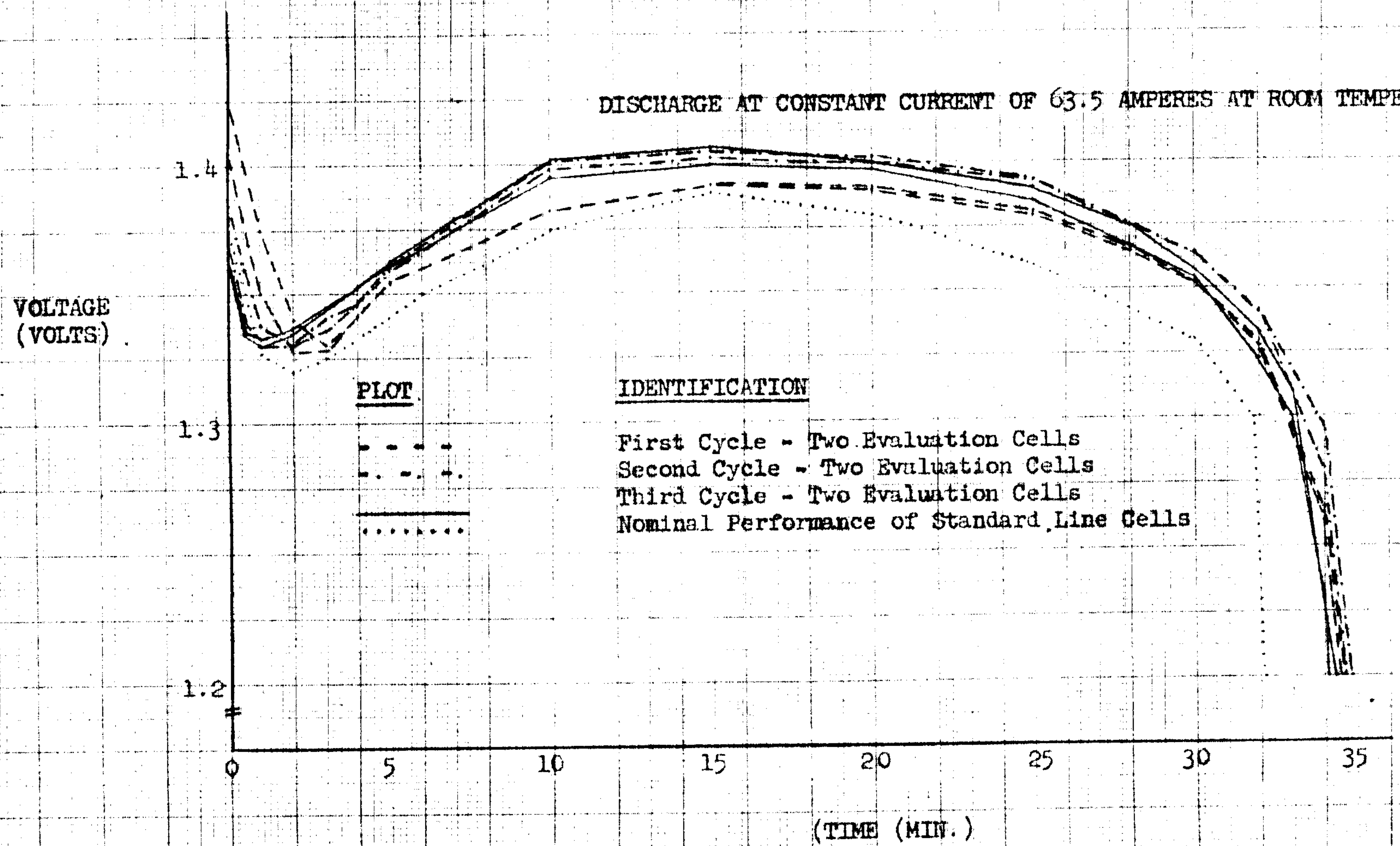

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FIGURE 3

MODEL 216 TEST CELL DISCHARGE CURVES

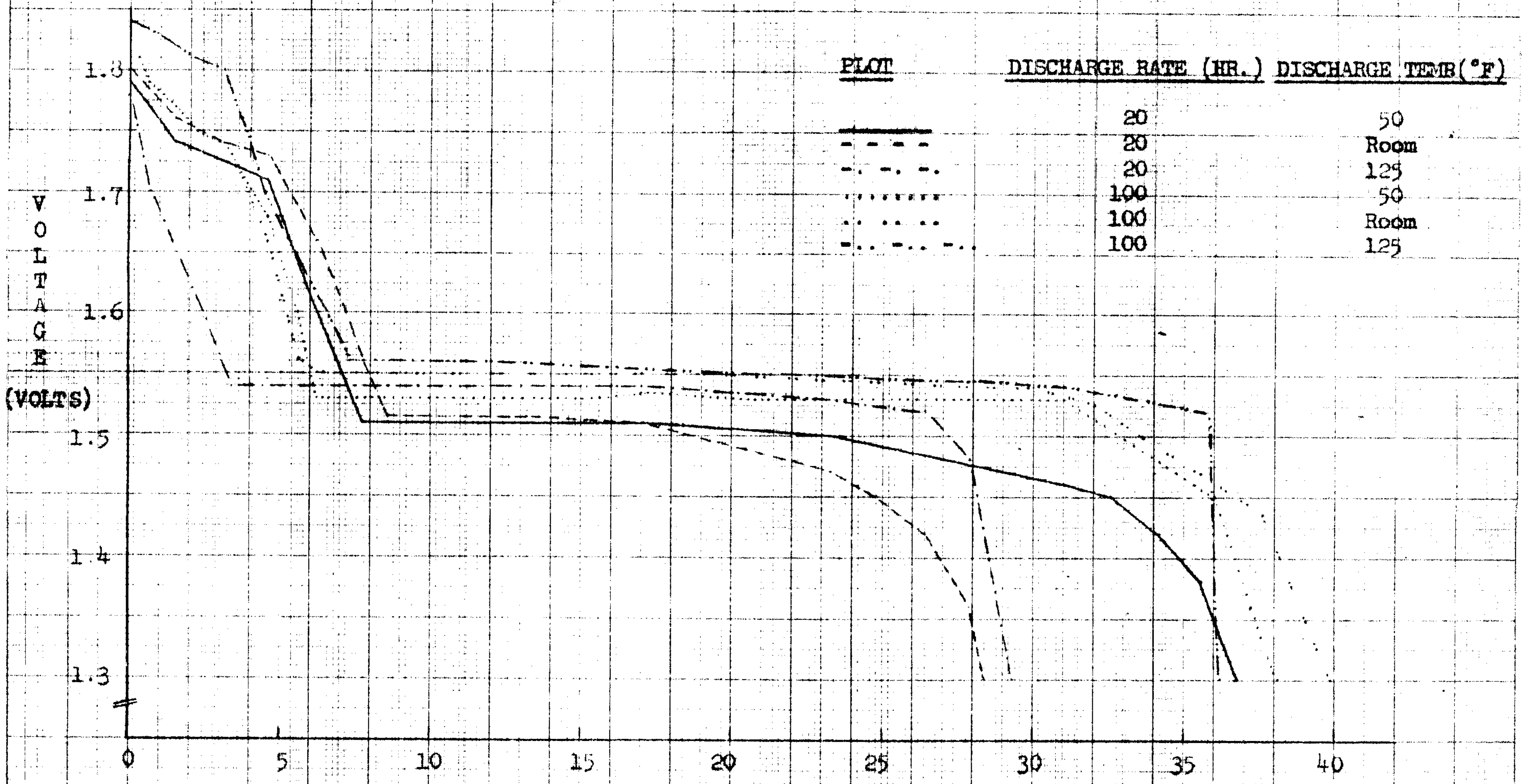

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FIGURE 4

MODEL 217 TEST CELL DISCHARGE CURVES

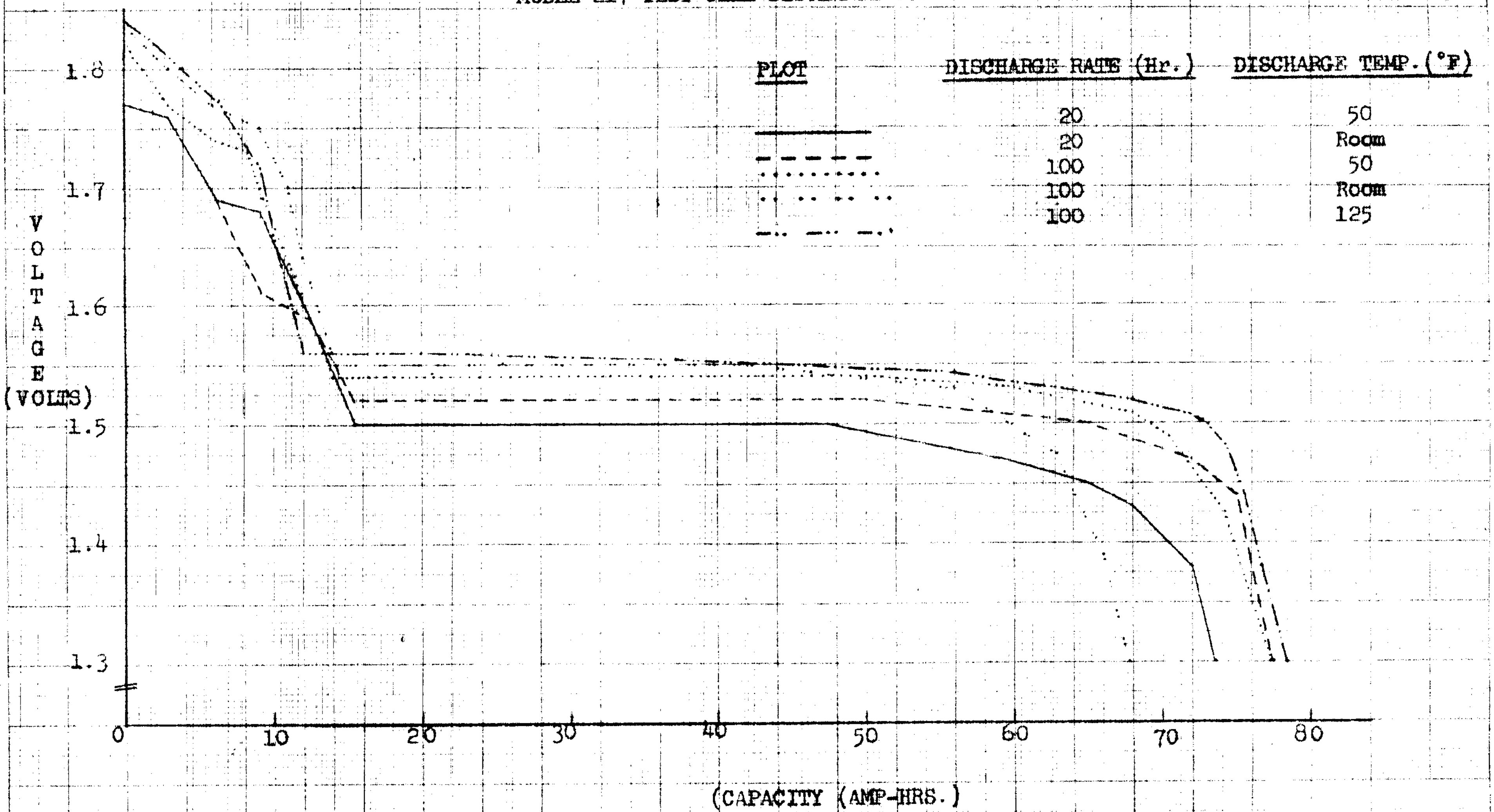

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FIGURE 5

MODEL 218 TEST CELL DISCHARGE CURVES

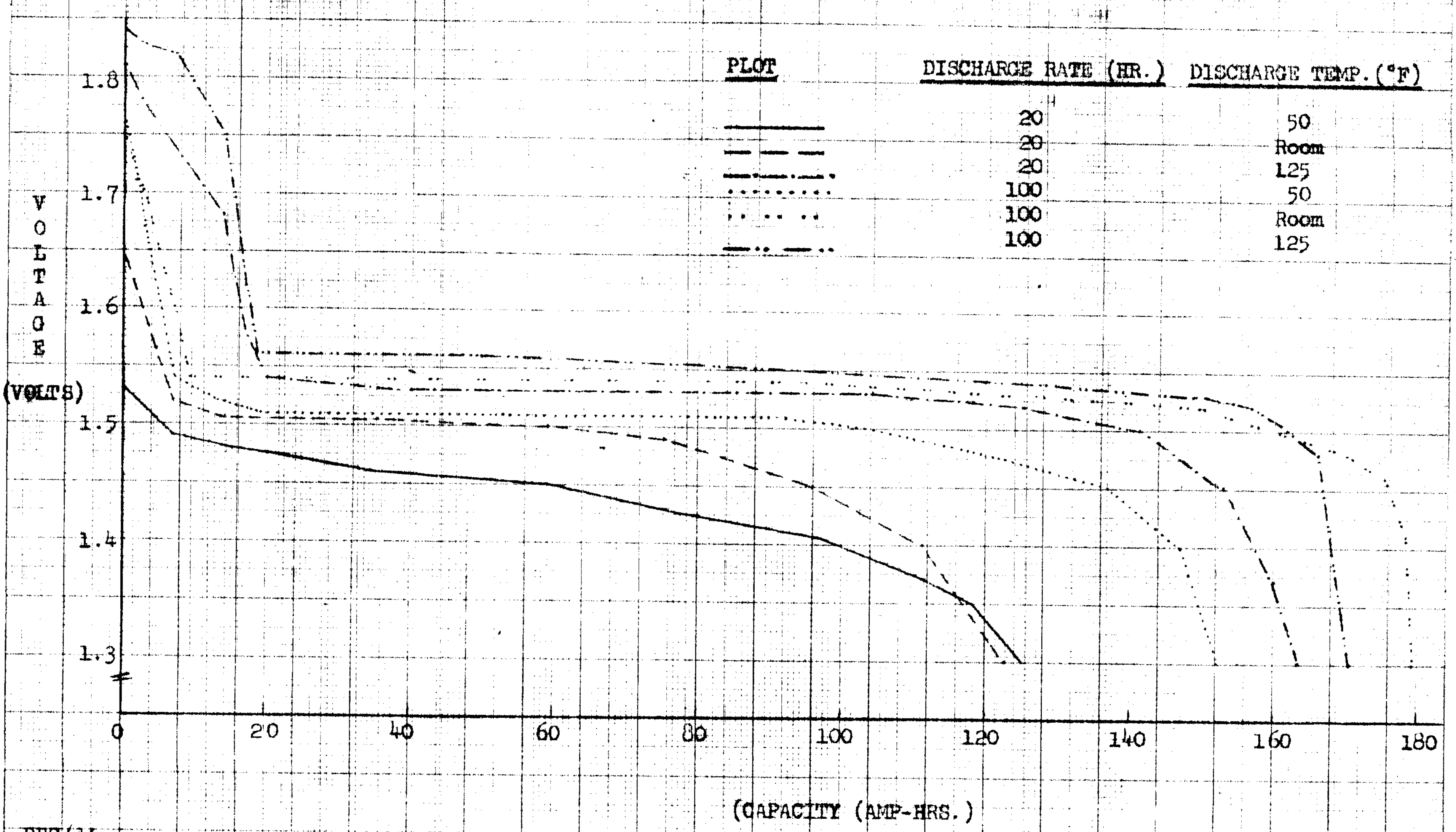

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FIGURE 6

VOLTAGE VS. CURRENT DENSITY
MODELS 216, 217, & 218

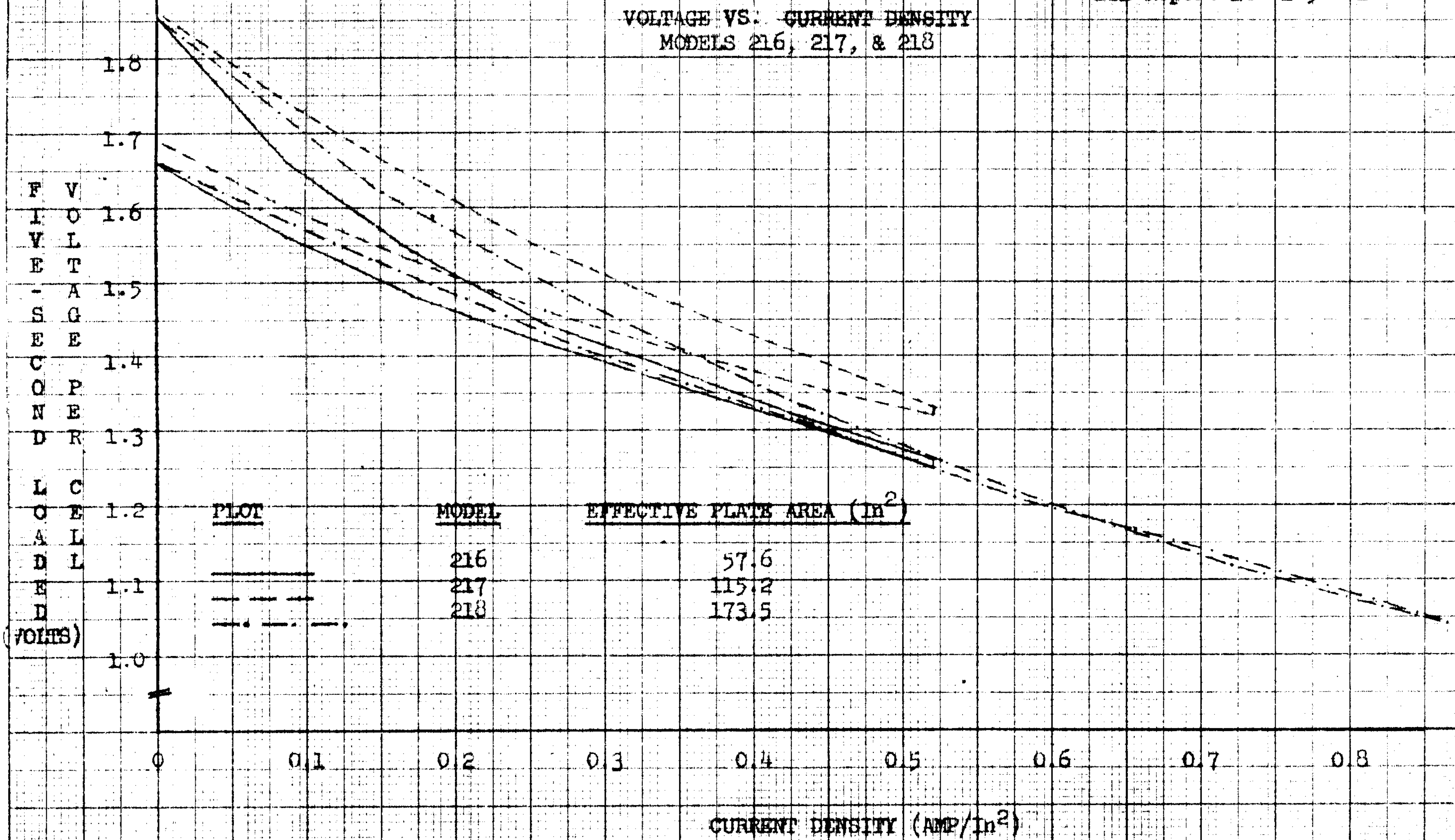

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FIGURE 7

EXPENDITURE CHART

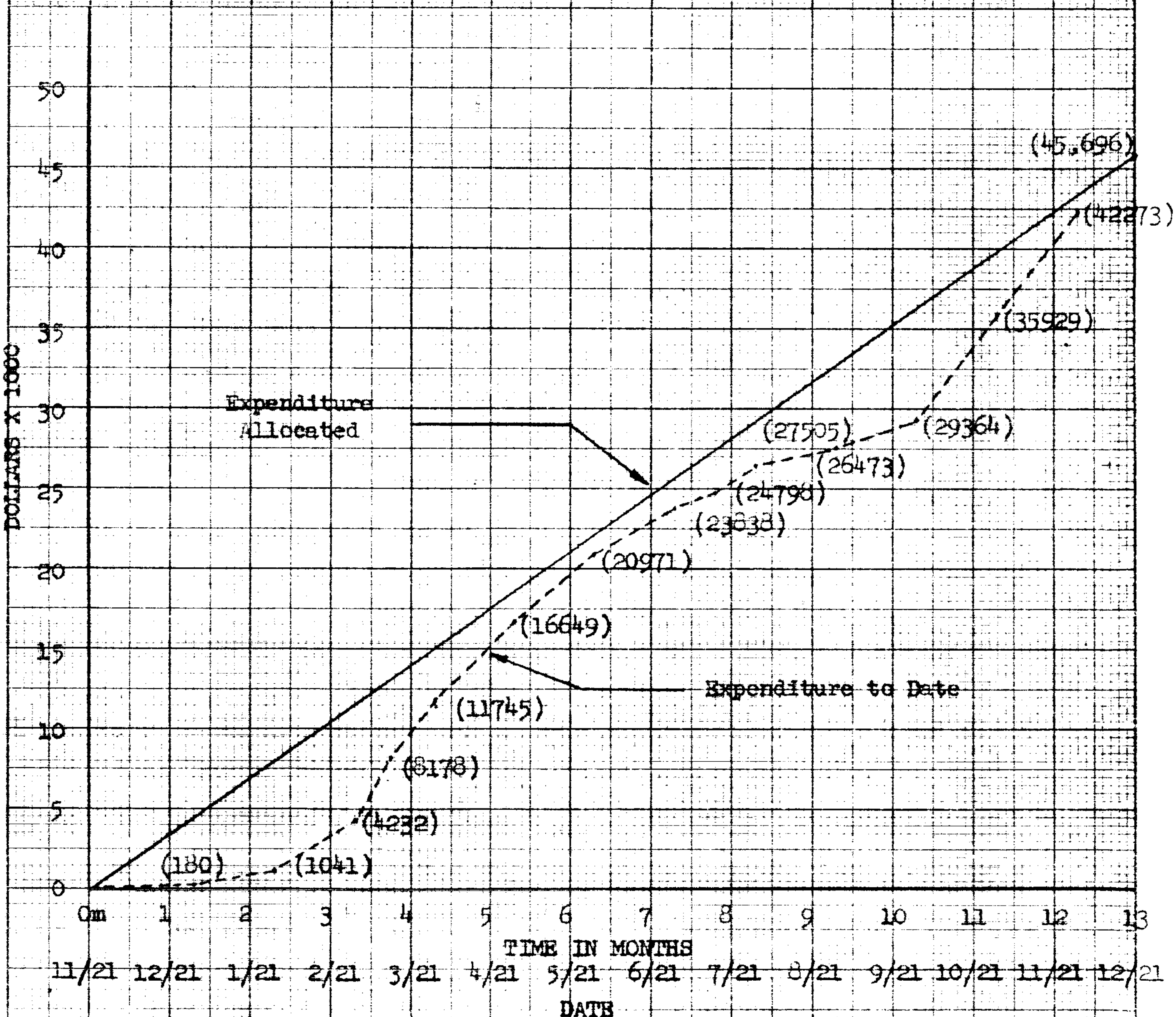

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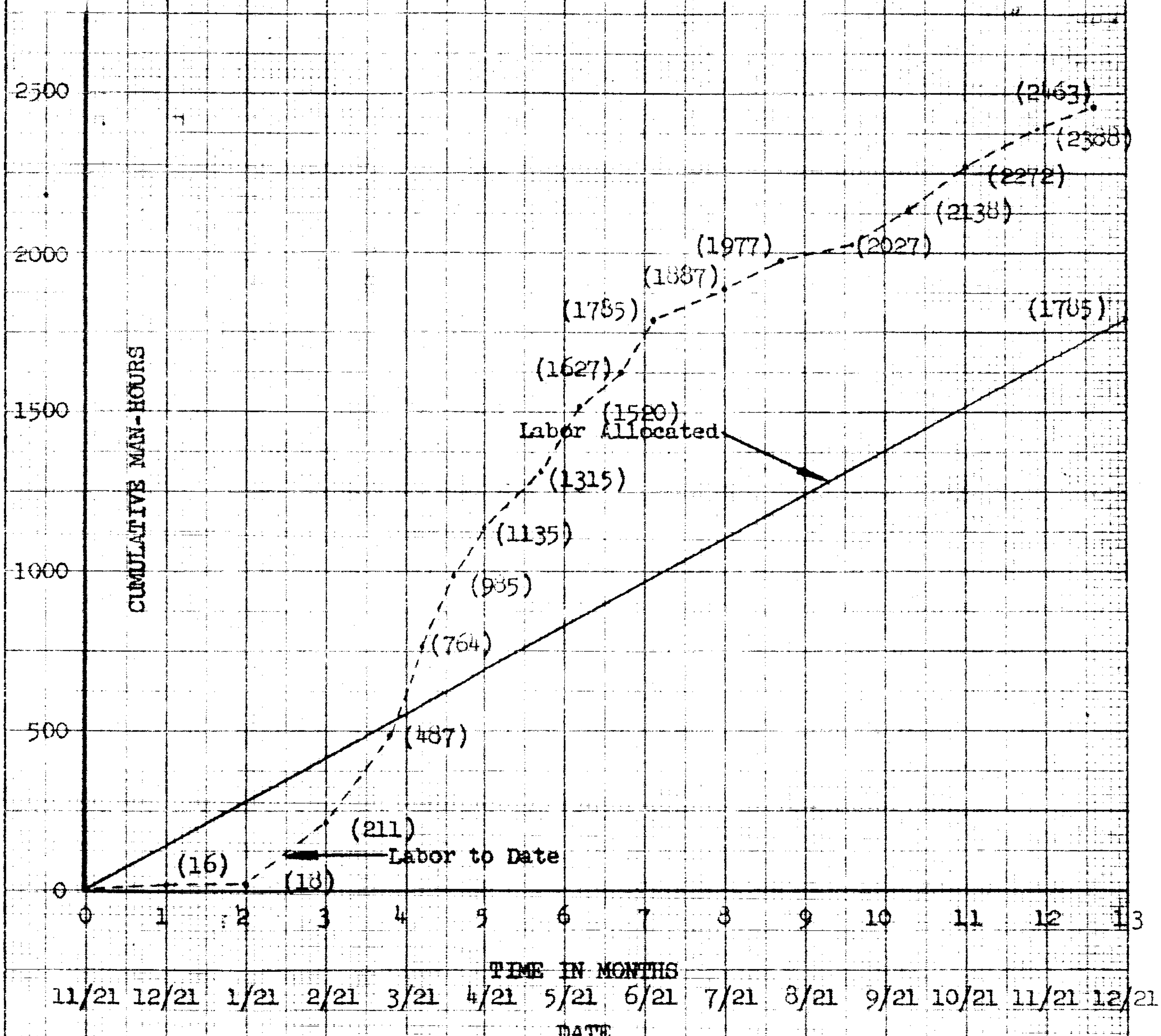
FIGURE 6

ENGINEERING LABOR



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